EOS Aura Validation Workshop
Lanham-Seabrook, MD
7 November 2001

Attendees: Don Anderson, Jim Anderson, John Barnett, Reinhard Beer, Phil DeCola, Anne Douglass, Jim Elkins, David Fahey, Lucien Froidevaux, John Gille, Ernie Hilsenrath, Daniel Jacob, Doug Kinnison, Mike Kurylo, Gil Leppelmeier, Jennifer Logan, Jim Margitan, Paul Newman, Ross Salawitch, Mark Schoeberl, David Starr, Kathy Thompson, Joe Waters, Darryn Waugh, Paul Wennberg, Diane Wickland, Steve Wofsy

Action Items/Assignments – Paul Newman

- These topics rose from the discussion at the end of the meeting. The persons identified are leaders for each subject, but are expected to seek input from other individuals

1. Collate the Aura/TC3/CRYSTAL TWP science goals – Douglass, Salawitch, Starr
   - There are some common goals and some conflicting goals
   - The emphasis on measurements in cloudy parts of the tropics for TC3 and CRYSTAL is somewhat at odds with Aura validation needs
   - Need to look more closely at the mini-mission concept (i.e., a series of small and distributed deployments), using Costa Rica as the deployment site
   - Froidevaux - If we go into an extremely cloudy region, we will have a difficult time meeting Aura goals
2. Produce recommendations for new and improved instruments, such as aerosol instruments, tropospheric ozone lidar, and a lighter version of the MkIV – Jim Anderson, Fahey, Toon, **Wennberg (lead)**
   - What kind of instrumentation?
   - Aerosol instruments in the range of 3 to 10 microns
   - Issue of tropospheric ozone lidar
   - Include making MkIV lighter
3. Identify science/measurement/logistic issues that will impact validation activities (e.g., H_2O intercomparison, platform capability improvements, etc.) – Friedl, Froidevaux, Jacob, Margitan, Newman
   - We need to fly new instruments in advance of major missions
   - If you are going to do a water vapor intercomparison or something similar, it would be useful to fly a mini-mission out of Costa Rica (for example)
   - What is the best place to go?
   - This group needs input from Douglass, Salawitch, and Starr (*et al.*) before they can address these questions
4. Develop concepts for a high-latitude mission – Fahey, (Newman), Santee, Tabazadeh (?), **Waugh**
   - Such a mission is necessary for validation; however, the group consensus places a lower priority on this mission than the tropical mission
   - Focus on some of the products that Waters and (perhaps) OMI need validated
   - This validation exercise likely would be a mini-mission
   - Focus on denitrification

- Jennifer Logan – How do we entrain more of the tropospheric community into this program?
  - We need to get INTEX to address Aura validation goals, and we need to better include INTEX in the Aura Validation Plan
    - Should address need for mini-missions
  - INTEX and NACP – Jacob/Logan, Ridley, Singh, Wofsy

Next Aura Validation Meeting(s)

- Schedule every four months

- The next meeting will be held 19-20 March 2002 in Pasadena, CA
  - Kathy (Wolfe) Thompson will work with Joe Waters to set a location

*** Meeting Notes ***

- The purpose of this validation working group meeting is to begin developing an implementation plan for the Aura validation needs as described in Version 1.0 of the EOS Aura Science Data Validation Plan, which is available on the EOS Aura web site
  - http://eos-aura.gsfc.nasa.gov/
- Per DeCola, the Conferees' Report has been released
  - The $15M hit to the EOS algorithms has been removed
  - This will allow instrument development prior to the Aura mission
  - There will be a $25M total reduction in the Office of Earth Science budget, but it is not clear where the reductions will take place

Aura Time Line - Mark Schoeberl
- Latest likely Aura launch date is mid 2004, but could happen earlier (late 2003/early 2004)
  - The uncertainty in the launch date must be considered in planning for missions requiring aircraft or balloon launches
  - To allow for further launch delay, it is felt that no major activities should be planned before 2005
  - We need a few months after launch for instrument performance assessments
  - No validation activities should take place within three months of launch to allow for the instruments to come on line and be placed in stable operating modes
- Current projection is that SAGE III will launch in December 2001
- Mike Kurylo has tasked Jim Margitan and Ross Salawitch to develop a plan for balloon continuity through the Aura launch

Aura Validation Process – Mark Schoeberl
- Validation for the stratosphere
  - Main science mission will be the Tropical Composition and Climate Coupling Experiment (TC^3)
  - Additional balloon launches at mid and high latitudes needed
    - There was some discussion of a plan to have balloon launches annually or semi-annually to provide some points of continuity to connect the time series from UARS with the time series from Aura
  - NDSC measurements provide longer-term validation (NO_2 column, ozone column, ozone and aerosol profiles, etc.)
    - NDSC plays an important role in validation of stratospheric species, but is less important for tropospheric species, in part because the NDSC stations are located in unpolluted locations
    - There is a strong need for sites measurements of constituents such as tropospheric ozone in polluted areas.
  - Why TC^3?
    - Sense of community interest in tropics
    - Strong tie-in to Aura science goals
    - Climate forcings are part of the NASA science plan
    - Relevance to both troposphere and stratosphere
    - Relevance to CRYSTAL
- Validation for the troposphere
  - With the current schedule, Aural will be launched too late for INTEX A with current plan
    - Can INTEX A be delayed?
    - INTEX A swapped with B?

- Why INTEX?
  - Intercontinental transport of pollution is of interest to Europe as well as US (and related to NASA science plan)
  - Importance of regional pollution to the global atmosphere (also related to the NASA science plan)

  Mini-missions using fixed payload (ozone, NO_2, NO, NO_y, HNO_3, H_2O, CO_2) generating profiles up through the troposphere
- Tropospheric ozone *in situ* data and airborne lidar profiles as part of TC3/TWP
- Steve Wofsy would like to include FTIR instruments located in the U.S., Daniel Jacob would like to include tropospheric lidars at Mike Newchurch's sites (U.S. and tropics)
  - AWI is working with Venezuela to develop a site in Merida that will ultimately, hopefully be included as part of the NDSC
- Want to combine an aircraft science mission with a satellite validation mission

SOLVE II – Mike Kurylo and Phil DeCola
- Kurylo and DeCola have worked with Chip Trepte to draft a white paper for SOLVE II
  - Wanted to issue an NRA with three components, including the ACMAP recompete
  - Jack Kaye wants to include hydrology and other components into the NRA, which has delayed the process
  - SOLVE II likely will be a single-aircraft campaign (i.e., DC-8) with some free-flying balloons, focused on calibration and validation with SAGE III

Aura Validation Instruments and Platforms – Summary of both stratospheric (S) and tropospheric (T) needs – Mark Schoeberl
- Instrument developments
  - Lightweight FTIR for balloon launches at mid and high latitudes (S)
  - Other lightweight instruments for balloons (S)
  - *In situ* instruments for DC-8 (T)
  - Tropospheric ozone lidars (ground-based and airborne) (T)
- Potential platforms
  - WB-57F – pallet for tropospheric profiles (T)
  - Global Hawk (S&T)
    - Potential as long-range survey platform
    - Never been used in mission – availability uncertain
    - Payload integration issues
  - Other platforms (e.g., ER-2, Altair) (S&T)

Overview of Aura Validation Requirements (with focus on correlative missions) – Lucien Froidevaux
- Lucien Froidevaux provided a summary of the Aura validation needs as stated in the Validation Plan
  - There were 22 balloon flights for UARS during the first two years following launch
  - None were made in the tropics.
- Copies of the presentation distributed to meeting attendees; other information available in Aura Science Data Validation Plan
- 'Core validation' lasts for about three years after launch, and includes an initial three-month instrument activation (and check-out) phase, followed by a six-month commissioning phase
  - Data will be delivered during commissioning phase

  Correlative data during the first 3 to 12 months after Aura launch will be useful; however, there will be no significant analyses (by Aura instrument teams) until 9 or 12 months post-launch because of other significant activities related to validation within each instrument team
- Profiles are a high priority for validation mission science goals
  - Balloon flights are the only means for mid to upper stratosphere (with good vertical resolution)

    - Flights (coordinated with Aura overpasses) from more than one location are deemed necessary
- Jim Anderson - It is important to combine remote observations with *in situ* on the same platform
    - This would help in understanding how to compare *in situ* observations with the remote satellite observations
    - There are other issues in connecting the satellite spatial scales with the *in situ* spatial scales
- Daniel Jacob – When discussing pollution levels as they refer to sampling and frequency issues, it is difficult to define 'clean,' 'moderate,' and 'heavy' because of the variables involved
- Daniel Jacob – Also need to consider marine boundary layer
- Conclusions
    - Continued planning and dialogue needed
    - The Aura Validation Plan (v1.0) is a useful starting point
    - The Aura validation needs cannot be met within the context of a few major missions
    - The aircraft/balloon community must work with Aura teams

Tropical Composition and Climate Coupling Experiment (TC^3) – Ross Salawitch
- The goals of the TC^3 mission are to define and understand the chemical boundary condition for the stratosphere with an emphasis on processes that affect ozone, and to define and understand the response of the atmospheric hydrological cycle to climate change
- Would like to do the whole suite of organics, which would require a whole-air sampler
- Deployment sites (high-altitude aircraft): NASA Dryden, Hawaii, and Guam
    - Sampling upwind, downwind, and inside regions of active convection in the Tropical Western Pacific (TWP) is crucial
    - Flights would combine Aura validation and science activities with local flights to the north and south, as well as 'stair-step' profiles from Dryden, Hawaii, and Guam
- Deployment sites (OMS balloons) – Juaziero do Norte, Brazil; Fort Sumner, NM
    - Observations in the TWP are highly desirable, but perhaps not feasible due to the need for water-landing capability
- Schedule
    - Observations in Northern Hemisphere winter (high, cold tropopause) and Northern Hemisphere summer (low, warm tropopause) are essential to achieve TC^3 science goals of defining the physical and chemical properties of the troposphere transition layer (TTL)
    - Multiple deployments (i.e., mini-missions) covering at least two winters and one summer provide the opportunity for Aura validation under different temperature and pressure conditions, and allows characterization of seasonal and interannual variability of TTL
        - Wofsy notes that many papers came out much later than STRAT because of the multiple-deployment aspect of the mission
        - Starr notes that there has been no distinction made between 'equatorial' vs. 'ITCZ' sites
        - Salawitch wants to go where the highest convection is in winter, which fluctuates with El Niño; Starr notes that the highest convection is over the islands
        - Schoeberl notes that it might be good to also fly in the Eastern Pacific in the summer and winter
        - Financial constraints must be considered
- If the ER-2 and WB-57F are involved, Guam may not be a suitable location
    - Would need 10-hour ER-2 flights to adequately sample region of active convection from Guam during Northern Hemisphere winter
- The long lead time for this mission could allow for new instrument development and sensor comparisons, including …
    - A lightweight ozone/aerosol lidar for the ER-2 or WB-57F
    - If feasible, a lightweight H_2O lidar would be a superb addition
    - Enhanced temporal sampling by WAS using cryogen traps
    - etc. …

    - Instrument development for total water, water isotopes, clouds/aerosols, and short-lived organics critical for TC^3 science goals occurred prior to CRYSTAL-FACE (and after the first draft of the TC^3 white paper)
- Paul Wennberg stressed building flexibility into the mission system to allow investigators time to develop instruments well in advance of the campaign
    - Reference SOLVE, where we were able to refocus the mission when SAGE III did not launch on schedule
- Jennifer Logan pointed out that the lack of a tropospheric component to TC^3 is an oversight both scientifically and for validation
    - The cloud cover common in the western Pacific is a concern for measurements that focus on validation, because many of the Aura retrievals are not possible in the presence of significant clouds

Intercontinental Transport Experiment – North America (INTEX-NA) – Daniel Jacob

- INTEX is the next NASA field mission to be sponsored by GTE
- Objective is to quantify the North American import and export of (1) atmospheric oxidants and their precursors, (2) aerosols and their precursors, (3) long-lived greenhouse gases and to relate this import/export to the surface sources/sinks and to continental boundary layer chemistry
- The science goals of INTEX are related to Aura science goals but, as currently formed, Aura data is expected to play a small role (if any) in the INTEX mission
- Even both INTEX missions cannot meet all of the validation needs of the TES instrument
- There will be two aircraft – NASA DC-8 and P-3
- Two phases – one in northern summer and one during northern spring
    - Both phases look at inflow and outflow of the North American continent
        - Inflow is expected to be a maximum during spring, and outflow is expected to be a maximum during summer
    - Could exchange the two; however, it is important to fly in 2004
    - Might consider doing back-to-back missions (i.e., 2004 and 2005)
        - If INTEX B is moved to spring 2004, it will almost certainly be too early to be a part of the Aura validation
    - Summer 2004 – INTEX A
        - Active photochemistry, biosphere
        - Aerosol radiative forcing
        - Carbon uptake
    - Spring 2006 – INTEX B
        - Maximum Asian inflow
        - Contrast with summer
- Integration of aircraft observations with satellite data and model information is critical to the objectives of INTEX-NA
    - Satellite observations – global and continuous, but few species and low resolution
    - Surface observations – high resolution but spatially limited
    - During TRACE-P, there were five models in the field as well as five satellite data products in near-real time
- INTEX-NA payload will follow that for TRACE-P, with some enhancements, improvements, and additions
- Recent TRACE-P workshop attended by Daniel Jacob and Paul Wennberg
    - We now have some mature nitric acid measurements – Talbot, CIMS (Viggiano, Arnold, Huie)
    - Discussed major instrument development need for a CO lidar
    - Considering some new species, especially ammonia, and improving chemical characterization of aerosol
- INTEX-NA has a number of links with atmospheric programs (note that dates may not be accurate)

    - *In situ* – North American Carbon Program (2002-), NOAA Northeast U.S. Study (2004), European UT/LS program (-2005), Asian APARE program [Yutaka Kondo] (ongoing)
    - Satellites – Terra [MOPITT] (1999-), ENVISAT [SCIAMACHY, MIPAS] (2002-), NMP/GIFTS (2003-), Aura (TES, OMI, HRDLS] (2004-), ESSP/OCO (2004-)
    - Modeling – EPA OAQPS/ORD climate change/air quality initiative (2001-2010)
- INTEX-NA flight types
    - North American outflow to Atlantic (DC-8, P-3) – follow TRACE-P model
    - North American inflow from Pacific (DC-8) – curtains parallel to coast
    - Transcontinental flights (DC-8) – curtains to define transcontinental gradients, inflow/outflow pathways
    - Continental boundary layer mapping (P-3) – relate gradients to sources, processing
    - Continental boundary layer – free troposphere exchange (P-3, DC-8) – determine outflow mechanisms, fluxes
    - Satellite validation (DC-8) – expand on TRACE-P model – expand on TRACE-P model
- Because the MOPITT data were critical to TRACE-P, they were analyzed without being specifically funded
    - MOPITT orbit track was an important factor in day-to-day flight planning; ~50% of flights had good opportunities for validation
    - Large range of vertical structures were sampled
    - Unavoidable time mismatch between satellite and aircraft was shown to be a non issue
- Flight plan does not have much incursion over the ocean
- Flight plan for spring mission is less involved than the summer issue, but there will be more focus on the Pacific coast
- Why does INTEX-NA need to go in 2004?
    - To maintain the momentum of GTE, a key program in tropospheric chemistry research
    - A three-year interval between missions is longer than it has ever been for GTE; however, such a delay is justified to exploit the richness of the TRACE-P data set and to set aside time for instrument development and intercomparison
    - A U.S. deployment will be relatively inexpensive
    - Aura validation needs can be addressed in INTEX-NA (B); INTEX-NA (A) will meet other satellite validation needs
    - Links with other aircraft programs include NOAA/Northeast, which *will* take place in 2004
- An important goal of INTEX-NA is to test the models by integrating aircraft and satellite data
    - What kind of information do you lose by not including an urban region?
- Challenges for INTEX to contribute to Aura Validation
    - Schedule
        - Swap A and B
        - Stick to summer 2004, spring 2006
        - Change to spring 2004, summer 2005?
    - Integrate Aura contributions to INTEX science goals

CRYSTAL – David Starr

- Dave Starr presented the scientific justification, goals, and implementation plan for CRYSTAL
- This mission focuses on cloud processes, and requires at least two aircraft to make measurements because the clouds are optically thick
- Although TC^3 and CRYSTAL have some common goals, it will be difficult to develop a payload for a combined TC^3-CRYSTAL either using two ER-2 aircraft or an ER-2 and the WB-57F
- The measurements in and around clouds limit the relevance of CRYSTAL to Aura validation
- Challenges for TC^3 CRYSTAL to contribute to Aura Validation:
    - Development of tropospheric component
    - Definition of mini-mission, "full" mission needs and goals
    - Payload
    - Location

- Seasons

North American Carbon Program (NACP) Field Campaign - Steve Wofsy

- Steve Wofsy described planned measurements to be obtained during the proposed NACP field campaign
- Some elements of the NACP are funded
- There are at least six different agencies interested in participating in the field campaign
  - Aircraft ascents every 2 days at 25 to 30 sites, from 0 to 7 km
    - Will measure CO_2, CO, CH_4 from a light aircraft with "turn key" instrumentation
  - Will conduct aircraft transects every 2 days at 2 to 4 sites, from 0 to 12 km
    - Will measure CO_2, CO, CH_4, H_2O, ozone, NO, NO_2, NO_y, PAN, etc.
  - Will have measurements from tall towers, 3 to 10 sites, of profiles of CO_2, CO, CH_4, and H_2O from 0 to 500 m; will also get fluxes using eddy correlation technique
  - Also hope to have profile measurements (LIDAR) and total column measurements (FTIR) from 3 to 10 sites.
    - Lidar would measure CH_4, CO, H_2O, ozone (???); FTIR would measure CO_2/O_2 ratio (e.g., column averaged CO_2 mixing ratio)
    - Hope to have some profilers in the tropics, as well as in North America

Aura Satellite Validation Using High-Altitude Aircraft in the Upper Troposphere and Lower Stratosphere: Performance Characteristics and *In Situ* Sampling Payloads – David Fahey

- David Fahey presented a comparison of platforms possible for high-altitude measurements
- ER-2 might be able to fly 10-hour sorties; however, the justification for such a duration would need to be exceptional
- WB-57F might be able to fly 8-hour sorties, if landing gear and weight issues can be resolved
- Jim Anderson would like to see an aircraft's ability to fly in convection and its vertical acceleration as criteria for selecting platforms
  - ER-2 will fly above convection, WB-57F can fly to the edges of anvils
- Global Hawk is able to operate within U.S. commercial air space
  - The Global Hawk would provide an unprecedented capability in terms of spatial sampling as this remotely piloted aircraft has a remarkable range; however, it is unclear how such an aircraft could be available to NASA (either through purchase or through lease of a military plane)
  - Specific maneuvers (e.g., a dip) can be programmed into the flight plan
- NOAA has a page in their five-year plan about the benefits of using the Global Hawk; however, funding is a real issue
- NOAA Forecast Systems Laboratory may be interested in using the Global Hawk (up to 300 aircraft) for their global sampling program

- Don Anderson made a few comments describing the Proteus aircraft
  - Flight duration up to 8 hours
  - Maximum altitude of 60,000 ft
  - Unless there is a marketing opportunity to build additional aircraft (more than one), there are no plans to produce any more aircraft

Discussion – Paul Newman

- Even under optimal circumstances, there are many validation needs that cannot be met within the context of these missions. The implementation plan must utilize mini-missions (other than those which may be part of TC^3) and balloon launches to satisfy these needs
- What are the science issues?
- Platforms and instruments? – P-3, DC-8, Citation (<10 km); ER-2, WB-57F, Global Hawk (10 to 20 km); balloons (>20 km)
- Three types of payload – remote, chemistry, particle

- ER-2 can operate out of Guam and Hawaii; WB-57F also can operate out of Kwajalein
- Issues
  - Instrument development?
    - Develop new instruments, update current instruments (e.g., make them smaller), refine current instruments for use on different platforms
  - H2O intercomparison?
  - Ditch some science goals? What are the top science goals that we need to address, and which are second priority?
    - Can we combine TC^3 and CRYSTAL-Pacific (TWP)?
    - Need to task a small group to refine the goals of both missions
  - Minimize the number of deployments?

Balloon Flights – Jim Margitan
- Margitan presented a vugraph showing the U.S. (large) balloon schedule for the UARS Correlative Measurements Program
- Strawman balloon flight plans for Aura validation
  - All flights from a midlatitude site (Fort Sumner, NM) during September
  - OMS *in situ* (ALIAS-II, CO2, LACE, ozone, H2O), MkIV, SLS, BOH, FIRS2, new *in situ* H_2O isotopes
    - May have to fly a combination of platforms to address individual science objectives
  - Science objectives
    - Observe the chemical state of the stratosphere during a time of near-peak chlorine loading and extremely low aerosol loading
    - Monitor trends in stratospheric CFCs, HC., HF, H_2O, and CH_4
    - Quantify stratospheric circulation by continuing the CO_2 and SF_6 time series
    - Develop new H_2O and H_2O-isotope capabilities for Aura validation and synergistic science

Next-Generation Airborne Gas Chromatograph for NASA Airborne Platforms – Jim Elkins
- First test flight will be in March 2002
- Potential platforms are ER-2, DC-8, WB-57F, and balloon gondola (in a pressurized container)
- PAN and Trace Hydrohalocarbon ExpeRiment (PANTHER)

Summary – Anne Douglass
- Implementation plan for Aura validation
  - TC^3 and CRYSTAL
    - Mini-missions, larger mission
    - Tropospheric component? (for TES, but also mission science goals)
    - Realistic definition to balloon launches
    - Remote sensing vs. *in situ* questions
    - Reasonable to expect latitude, seasonal, conditions explorations associated with mini-missions?
  - INTEX
    - If we must take a chance to miss one
      - INTEX-A in summer 2004 (50-50 chance it will happen than three months post-launch)
      - INTEX-B in spring 2006 (expect other seasons associated with TC^3?)
  - Per Diane Wickland, the North American Carbon Program is not likely to take place until 2005; working toward 2004 would be extremely difficult
  - Global Hawk??? – This is a powerful platform; however, the cost ($18M) could be prohibitive

    - Don Anderson - We should recognize the value of this platform and do some Paul Newman/David Fahey-type analyses to determine the potential and feasibility of this platform
- There are a number of TES mini-missions that will complement the Aura validation process
- What is the feasibility of exercising some deployment strategy using Costa Rica and the WB-57F?
- There will not be a white paper for mini-missions; we are trying to develop a plan for validation activities that takes us up to the Aura launch (and beyond)